Jet Propulsion Laboratory
California Institute of Technology

JPL Case Study

June 2014

Catcher in the Wrong:
The Genesis Canister Lift Incident

In 2000, the Genesis sample return canister detached from a lift fixture fitting and lightly impacted the transportation dolly just prior to thermal vacuum testing at JPL. No spaceflight hardware was damaged, and there was no significant injury to personnel. The drop occurred because the swivel hoist ring fasteners had not been fully threaded and torqued, and test personnel failed to observe that the lift fixture components were coming apart.

Background

Test of spaceflight hardware. Satellites and spacecraft are lightweight structures designed to withstand the stress of launch and spaceflight, but their design is not optimized for handling in a terrestrial environment. Despite the extremely high unit value of these assets, and despite the resources devoted to safeguarding them, dropping the delicate hardware on concrete is not that rare an occurrence. In a famous 2003 incident, the NOAA N-Prime satellite sustained heavy damage when it was rotated from a vertical to a horizontal position without first bolting the satellite to the lift fixture.

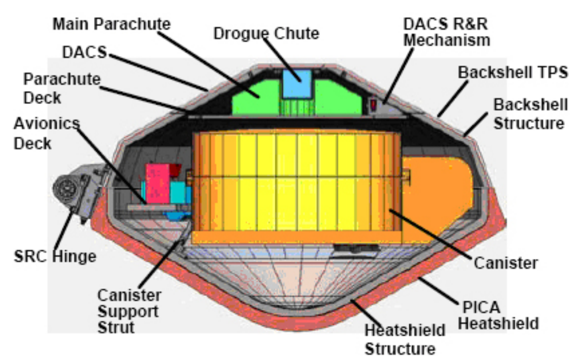
After flight hardware components are fully integrated, there are times when a major assembly or the complete system must be hoisted. It must be lifted onto a shaker for dynamic testing, into a thermal-vacuum chamber for thermal testing, and onto a launch vehicle. Typically, it is the actual flight hardware intended for launch that serves as the test article, rather than using a spare.

JPL has well-established and documented procedures for critical lifts:

1. JPL personnel are not allowed to handle flight hardware without obtaining certification.
2. A procedure for critical lifts (Reference 1) provides an overview of each activity, identifies the supporting team members and their roles, and identifies the necessary safety protocols.
3. JPL uses an Instructions for Build, Assembly & Test (IBAT) form to plan operational steps to be performed on hardware during fabrication, handling, and test. The IBAT serves as a checklist of the steps to follow during the execution of operations; afterward it becomes a controlled record of what was done to spaceflight hardware. The IBAT replaces a prior Assembly & Inspection Data Sheet (AIDS) that served a similar function.

Genesis project. Genesis was a mission launched in 2001 to collect solar wind particles and return them to Earth. These particles were captured using a Sample Return Capsule-- a 60-inch diameter cone containing a heat shield, backshell, sample return canister, parachute system, and avionics. The sample return canister was an aluminum enclosure in the center of the capsule containing the specialized collector arrays and ion concentrator.

JPL managed the Genesis project, and it was responsible for developing, integrating, and testing the sample return canister and collector arrays. In May 2000, JPL prepared for thermal-vacuum testing of the canister.



Genesis Sample Return Capsule (SRC)

"Catcher in the Wrong"

Genesis Canister lift incident

Proximate cause:

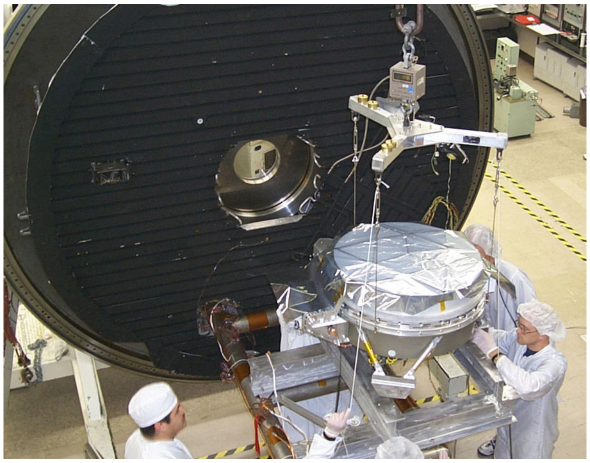
The Genesis staff failed to observe that the fixture was coming apart at the tension bolts.

Root Cause:

The lift procedure did not require adequate checking of all fasteners prior to attaching the fixture to the hoist.

The Mishap

While the Genesis Canister was being lifted from the transportation dolly at JPL in preparation for thermal vacuum testing, the lift fixture detached at one of the three swivel hoist ring tension fittings (Reference 2).



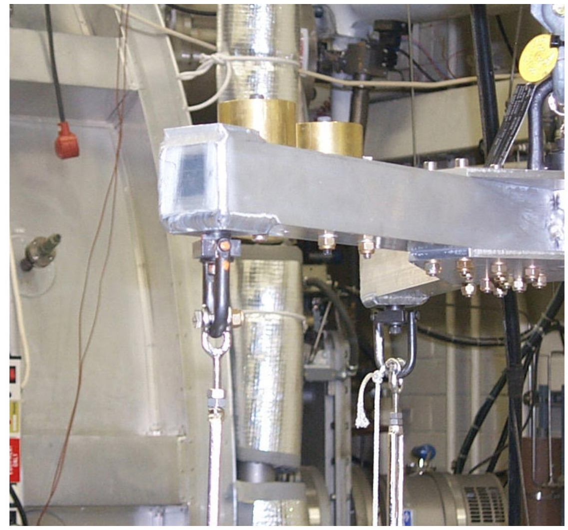
Genesis Canister being lifted for mounting on the test chamber door. (The swivel hoist ring that separated from the spreader bar is visible, attached to the top of the rightmost of the three hoist cables.)

Just prior to mounting on the test chamber door, one corner of the Canister fell approximately 5 centimeters (2 inches) back onto the dolly. Nearby personnel cushioned the fall to achieve a soft landing on the dolly, and there was no damage to the canister or support equipment, or serious injury to personnel. (One of the test personnel had his finger caught between the bottom of the Canister and the transportation dolly. While he perceived the pinch to his finger, he was not injured. Some minor scratches were evident on the bottom where the Canister contacted the dolly, but no gouges were seen. The loose shackle swung and contacted one of the stiffening ribs on the Canister cover, leaving a very small ding on its corner.)

Mishap Investigation

Post-incident inspection revealed that the threaded fastener had backed out of the Mechanical Ground Support Equipment (MGSE) fixture and became detached. The bolt that released had backed out at least a quarter of an inch, and this would have been easily observable. A second bolt was also backed out, but not as far. Additionally, the fasteners at the other tension fittings, and at the upper hoist point, were found to be only hand-tight.

The lift fixture assembly had been subjected to its annual proof test 8 months earlier under the supervision of JPL Quality Assurance (QA). Subsequently, the tension cables and associated hardware had been disassembled from the fixture, and then later reassembled by a vendor following vendor dye penetrant inspection of the swivel hoist fittings. After the dye penetrant inspection, the fittings were merely threaded to the lifting fixture for delivery rather than assembled and torqued per an AIDS. The fixture had last been used to lift the Canister two days prior to this incident.



Close-up of the swivel hoist ring fitting

The fixture was visually inspected prior to the drop incident, but the hoist rings were not checked for tightness. There is no evidence that the hoist ring fasteners had been properly torqued since the proof test. The procedure governing the Canister lift operation (Reference 3) did not require adequate checking of all fasteners prior to attaching the fixture to the hoist.

Aftermath

After verifying that the flight hardware was undamaged and the MGSE was sound, work was continued to mount the flight Canister to the thermal vacuum chamber and continue the test. An AIDS was written to document proper assembly of the MGSE fixture with QA verification. Other procedures and checklists were also updated to include post-NDI reassembly and torqueing instructions for MGSE (Reference 4). A mishap report and a NASA lesson learned were written to increase awareness of the incident.

Discussion

1. Are there any similarities between the Genesis and the NOAA N-Prime lift incidents? (See the next page for more details on the N-Prime incident.)

2. *True or false*-- the Genesis Canister near miss suggests that the prudent project manager should identify easily dispensable members of the project team and position them under the lift operation to "cushion" any fall.

   Is this "best practice" employed on your project? How would you know? [Was the "catcher in the wrong? If the test article had been heavier, [redacted] would likely have been maimed.] JPL can grant a Category A waiver that does permit personnel to work under a suspended load with adequate risk evaluation (per NASA-STD-8719.9, Appendix A).

3. If you answered Item #2 as "False," what steps would you take to separate non-operational or unauthorized test personnel from the lift operation? [Ron Welch: As part of the pre-lift briefing and discussion, it is important to identify the critical lift team, identify their specific assignments, and make sure they understand them.]

4. Discuss the proximate (i.e., immediate) cause of the drop? The Genesis staff failed to observe that the fixture was coming apart at the tension bolts.

   What was the root cause? (A root cause is an initiating cause of a causal chain that leads to an outcome.) The lift procedure did not require adequate checking of all fasteners prior to attaching the fixture to the hoist.

   Where there any contributing causes?

5. What measures might have prevented the use of MGSE with un-torqued fasteners? [The fabrication or test organization could have thoroughly inspected all MGSE for fastener engagement and specified torque prior to delivery for use by a project. Where feasible, threaded components that are to be placed under tension could be designed with a positive locking device, or fastener heads could be spot bonded. Or the hoist ring could be replaced with longer bolts. While not every MGSE bolt needs to be torqued before a lift, all critical load path elements should be visually checked for thread engagements and torqued where necessary in accordance with the procedure (IBAT)]

6. What measures might have facilitated visual inspection of the MGSE, such that the un-torqued fasteners could be spotted? [The fastener heads could be torque-striped to enhance visual inspection of thread engagement.]

7. The AIDS (or IBAT) form is a "checklist" approach to recurrence control. With over a decade separating us from the 2000 incident, what other measures might also counter the "Cycle of Forgetfulness?" [Critical lifts subject to training and certification, slow pace, triple-checking, QA oversight, two-person rule, other process enhancements. The CogE class could be opened to anyone present on the floor, and to those who take the flight hardware handling course.

   Ron Welch: the pre-lift briefing utilizing the checklist is the most efficient and effective current method for assuring that all preparatory work and inspections have been completed. The hard part is getting the lift leads to utilize the form the way it was intended]

References

1. JPL Critical Lift Checklist, Rev. 1, DocID No. 78603, November 21, 2013.
2. "Canister Lifting Incident," PL Problem/Failure Report No. Z69149, May 3, 2000.
3. JPL Assembly and Inspection Data Sheet (AIDS) No. 216421, May 2, 2000.
4. "Safety Requirements for Mechanical Support Equipment for JPL Critical Items Equipment," JPL D-51956, Rev. B, December 23, 2013, p. 65.

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Appendix:
NOAA N-Prime Satellite Topple Incident

Abstract:

The NOAA N-Prime satellite mishap is the most recent in a history of spaceflight hardware drops or near drops demonstrating the potential for major damage from ground handling of completed space systems. Assure rigorous adherence to process discipline; procedure development, review and approval; configuration management for ground support equipment; and enforcement of rules and regulations through training programs and improvements in organizational structures and practices.

Event Description:

A mishap occurred to a NASA Goddard Space Flight Center managed system at a non-NASA facility. During a September 2003 procedure, rotating the Television Infrared Observational Satellites (TIROS) National Oceanic and Atmospheric Administration (NOAA) N-Prime satellite was required. As the satellite was being rotated from a vertical to a horizontal position, it toppled from the Turn-Over Cart (TOC) and fell onto the concrete floor (Figure 1). Although no personnel were injured, the satellite sustained heavy damage (Figure 2).

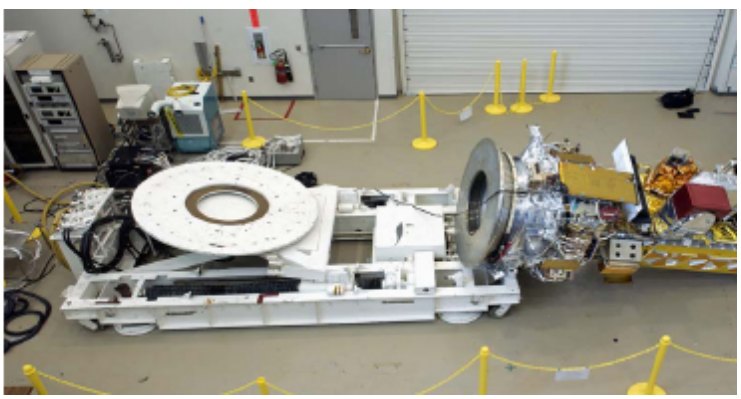

Figure 1. NOAA N-Prime satellite fell off the Turn-Over Cart

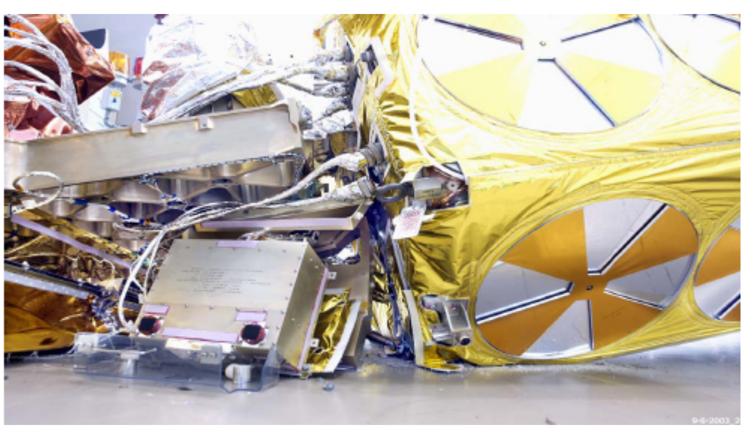

Figure 2. NOAA N-Prime sustained heavy damage

The planned procedure was to remove and reinstall one of the instruments onboard the satellite. This procedure required the satellite to be tilted to the horizontal position using the TOC. The satellite fell to the floor as it reached 13 degrees of tilt. The proximate cause of the fall was the failure of the operations team to follow procedures for configuring the TOC: the 24 bolts that secure the satellite's TOC adapter plate to the TOC (Figure 3) were not installed and inspected (Reference (1)). While the TOC was in a common staging area, another project had removed the 24 bolts from it, an activity that was not communicated to the NOAA project team.

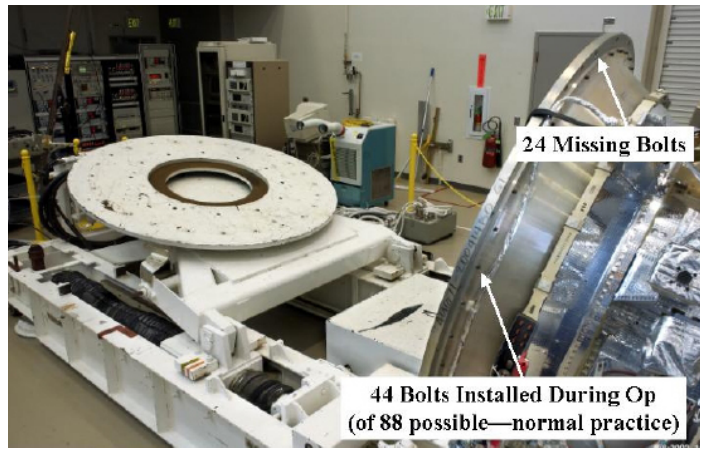

Figure 3. The 24 bolts used to secure the satellite to the TOC were not installed

The NOAA N-Prime Mishap Investigation Board (MIB) report (Reference (1)) identifies the following root causes of the mishap:

1. The operations team failed to execute established satellite handling procedures, including physical verification and quality assurance (QA) witnessing of the operation, and such procedural violations were routinely practiced.
2. This lack of procedural discipline (Item 1) stemmed from complacent attitudes toward routine satellite handling, poor communication and coordination among operations team, and poorly written or modified procedures.
3. Integration and test (I&T) supervisors routinely permitted the waiving of a safety presence, late notification of government inspectors, poor test documentation, and misuse of procedure redlines. Hurried planning for the instrument replacement operation was also a factor.
4. The unsafe supervision practices were rooted in an ineffective system safety program in which the available resources, safety guidance and safeguards, and oversight by program management were inadequate.

5. In-plant government representatives failed to provide QA and safety oversight, and they failed to identify and demand correction of the deficiencies that led to the mishap.
6. NASA's failure to correct program deficiencies was due to inadequate resource management, an unhealthy organizational climate, and the lack of effective oversight processes.

A planned addition to a series of global weather forecasting satellites, N-Prime was in an advanced stage of testing when the mishap occurred. Damage to the chassis, components, and at least 2 of the 6 instruments was estimated at $135 million (Reference (2)).

References:

(1) NOAA N-PRIME Mishap Investigation Final Report, National Aeronautics and Space Administration, September 13, 2004.

(2) Jason Bates, Space News, October 18, 2004.

(3) Genesis Canister Lift Incident, NASA Lesson Learned No. 0914, NASA Engineering Network, July 20, 2000.

(4) Post Mission Hardware Drop Incident, NASA Lesson Learned No. 0621, NASA Engineering Network, April 14, 1999.